

# Ecological momentary assessment of food perceptions and eating behavior using a novel phone application in adults with or without obesity

Alabduljader, Kholoud; Cliffe, Marion; Sartor, Francesco; Papini, Gabriele; Cox, W. Miles; Kubis, Hans-Peter

**Eating Behaviors**

*DOI:*
10.1016/j.eatbeh.2018.05.007

Published: 01/08/2018

Publisher's PDF, also known as Version of record

Eating Behaviors 30 (2018) 35–41

Contents lists available at ScienceDirect

Eating Behaviors

journal homepage: www.elsevier.com/locate/eatbeh

# Ecological momentary assessment of food perceptions and eating behavior using a novel phone application in adults with or without obesity

Kholoud Alabduljader[a,c], Marion Cliffe[b], Francesco Sartor[d], Gabriele Papini[d], W. Miles Cox[a], Hans-Peter Kubis[a,*]

[a] College of Health and Behavioral Sciences, Bangor University, Bangor, UK
[b] Department of Nutrition and Dietetics, Betsi Cadwaladr University Health Board, Bangor, UK
[c] Department of Physical Education and Sport, College of Basic Education, The Public Authority of Applied Education, Kuwait
[d] Department of Personal Health, Philips Research, Eindhoven, Netherlands

ARTICLE INFO

*Keywords:*
Obesity
Food reward
Ecological momentary assessment
Craving
Eating

ABSTRACT

We developed a smart phone application to measure participants' food-reward perceptions and eating behavior in their naturalistic environment. Intensity ratings (0 - not at all to 10 - very strongly) of perceived anticipation of food (wanting) and food enjoyment at endpoint of intake (liking) were recorded as they occurred over a period of 14 days. Moreover, food craving trait, implicit and explicit attitude towards healthy food, and body composition were assessed. 53 participants provided complete data. Participants were classified by percentage of body fat; 33 participants with lower body fat (L-group) and 20 with higher body fat (H-group; ≥25% body fat for males and ≥32% for females). L-group participants reported 6.34 (2.00) food wanting events per day, whereas H-group participants recorded significantly fewer food wanting events (5.07 (1.42)); both groups resisted about the same percentage of wanting events (L-group: 29.2 (15.5)%; H-group 27.3 (12.8)%). Perceived intensity ratings were significantly different within the L-group in the order liking (7.65 (0.81)) > un-resisted wanting (leading to eating) (7.00 (1.01)) > resisted wanting (not leading to eating) (6.02 (1.72)) but not in the H-group. Liking scores (L-group: 7.65 (0.81); H-group: 7.14 (1.04)) were significantly higher in L-group than in H-group after controlling for age. Our results show that individuals with higher percentage of body fat show less food enjoyment after intake and reveal no differentiation in intensity ratings of perceived anticipatory and consummatory food reward. These results are consistent with a hypothesized reward deficiency among individuals with higher percentage of body fat.

## 1. Introduction

In obesity, the mechanisms behind the failure of the homeostatic regulatory system to maintain energy balance in the face of hedonic incentives and drives towards consumption of food are still debated (Mela, 2006; Münzberg, Qualls-Creekmore, Yu, Morrison, & Berthoud, 2016; Yu et al., 2015). To prevent and treat obesity, increasing attention is paid to understanding reward driven eating. Reward response in eating has been divided into anticipatory reward, wanting, which is connected to the intensity of motivation to engage in eating, and consummatory reward, liking, which relates to the pleasure derived from eating (Berridge & Robinson, 2003; Mela, 2006; Stice, Spoor, Ng, & Zald, 2009). Brain imaging studies suggest that subjects with obesity compared with lean subjects have a higher anticipatory reward response to food cues (Nummenmaa et al., 2012; Stice, Spoor, Bohon, Veldhuizen, & Small, 2008). Nevertheless, the meso-limbic reward system showed less activation in response to food intake in individuals with obesity, suggesting that consummatory reward deficiency could be a contributing factor in overeating (Stice et al., 2008). An overarching finding is the involvement of alterations in dopamine dependent brain circuits thought to be influential in the observed alteration in reward anticipation, learning, and response (Berridge, 2009; Volkow et al., 2008; Wang et al., 2001). It is hypothesized that, as a result of overexposure, altered incentive salience in people with obesity leads them to expect more reward from a particular food than consumption of it delivers (Berridge, 2009).

These studies of anticipatory and consummatory food reward were conducted in artificial laboratory situations. Reward perceptions of individuals in their own environment with their unique externally and self-imposed food cues and choices have rarely been investigated. This might provide a different behavioral context to further our understanding of interactions between incentives and reward outcomes to

* Corresponding author.
*E-mail address:* pes203@bangor.ac.uk (H.-P. Kubis).

https://doi.org/10.1016/j.eatbeh.2018.05.007
Received 29 November 2017; Received in revised form 8 May 2018; Accepted 10 May 2018
Available online 12 May 2018

add clarity to existing theories of the role of food reward in obesity.

Ecological momentary assessment (EMA), which is described as repeated real-time sampling of a person's current behavior and/or experiences in their natural environment, has been used to explore some aspects of eating behavior in relation to obesity (Engel et al., 2016). Goldschmidt et al. (2017) studied non-hunger eating and perceptions of overeating in adults with obesity. However, perceived food wanting, including food wanting that was resisted, has not yet been investigated in real life situations.

To address the gap in our understanding of people's eating behavior we developed a smartphone application to allow participants to record the spontaneously occurring patterns of food wanting and liking in real-time in their natural environments. We recorded the intensity and frequency of explicit food wanting, the perceived motivation to consume food. Uniquely, the phone application enables participants to rate the intensity of their wanting of food whenever it reaches consciousness and to record whether it leads to food intake or not. Using this measure, hedonic wanting is not differentiated from homeostatic aspects (e.g. hunger). Liking ratings recorded here capture the perceived pleasure or enjoyment derived from eating and includes palatability and physiological responses from the gastro-intestinal (GI) and endocrine systems. It is measured at the endpoint of food intake and is therefore considered to be a measure of consummatory reward. To complement the phone application data and to improve the potential for interpretation, we additionally measured participants' food craving trait and their implicit and explicit attitudes towards healthy food. These are known to be relevant for food choice and eating behavior and are particularly altered in individuals with obesity (Pelchat, 2002; Roefs & Jansen, 2002). Identification of participants with obesity was based on percentage of body fat (Seger et al., n.d.).

We hypothesized that participants with higher percentage of body fat (H-group) would display reduced consummatory reward perception (liking ratings) compared with participants with lower percentage of body fat (L-group) in accordance with the reward deficiency theory. Secondly, because we expected that individuals with a higher percentage of body-fat would be more driven by hedonic motivation, we hypothesized that food wanting and food craving would be more strongly associated among participants with a higher percentage of body-fat than among individuals with a lower percentage of body-fat.

## 2. Material and methods

### 2.1. Participants

The protocol of this study was approved by the North Wales Research Ethics Committee in accordance with the Declaration of Helsinki, REC 13/WA/0236. Participants were adults from the North Wales area, aged 18–65, who responded to adverts in university and health board sites. Smartphone users in all weight categories were invited to apply. Eligibility of potential participants was assessed by phone prior to arrangement of their initial appointment. Participants with conditions known to influence appetite, including diabetes, cancer, depression and eating disorders were excluded, as were participants on medications known to influence appetite, such as antidepressants and corticosteroids. Additionally, people who worked on night shifts and those who could not access their phones while at work were excluded.

In total 84 participants were recruited, 28 of whom dropped out of the study, and three were excluded because of equipment malfunction or atypical dietary practice, such as fasting. The remaining 53 participants provided complete data. Participants were classified by percentage of body fat according to the Obesity Algorithm (Seger et al., n.d.). Females with a percentage of body fat $\geq 32\%$ and males with a body fat percentage $\geq 25\%$ are classified as having obesity (H-group). Classification by body fat percentage was chosen as a more specific measure of adiposity than the more commonly used proxy measure of Body Mass Index (BMI), which does not differentiate between fat and lean tissue (Kyle, Piccoli, & Pichard, 2003; Shah & Braverman, 2012). Body fat percentage has been shown to be of importance in food reward (Stice & Yokum, 2016). Data from 33 participants with low percentage of body fat (L-group) and 20 with high percentage of body fat (H-group) were analyzed.

### 2.2. Measures and procedures

Baseline characteristics of age, sex, weight, height and body composition were recorded at entry. Body composition and weight were assessed by researcher via bio impedance measurement (TANITA BC 418 MA system) to estimate percentage of body fat. Height was measured using a wall stadiometer. Furthermore, questionnaires and the computer task were completed once prior to the start of phone application recordings.

#### 2.2.1. Food craving

Participants completed the reliable and validated Food Craving Questionnaire (FCQ-T) (Cepeda-Benito, Gleaves, Williams, & Erath, 2000); with 39-items, craving is measured as a multi-factorial concept using a 6-point Likert-type scale from 1 (never) to 6 (always). The FCQ-T estimates the strengths of the following domains: (T1) intentions and plans to consume food; (T2) anticipation of positive reinforcement that may result from eating; (T3) anticipation of relief from negative states and feelings as a result of eating; (T4) possible lack of control over eating if food is eaten; (T5) thoughts or preoccupation with food; (T6) craving as a physiological state; (T7) emotions that may be experienced before or during food cravings or eating; (T8) environmental cues that may trigger food cravings; and (T9) guilt that may be experienced as a result of cravings and/or giving into them. The total sum score estimates trait craving intensity across the 9 dimensions.

#### 2.2.2. Explicit attitude

The explicit attitudes towards healthy food questionnaire was adapted from Courneya and Bobick (2000) by David Markland, Bangor University (Alshubrami, Alrajhi, Cox, & Kubis, 2017). When previously used with participants with obesity, this questionnaire predicted weight loss (Alshubrami et al., 2017). This questionnaire assesses explicit attitudes towards low fat, low sugar, high fibre foods, categorized as 'healthy', by asking participants to scale their attitudes to these foods. Eight elements were included in the questionnaire (e.g., enjoyable/not enjoyable, good/bad) to determine the main concept: "For me, eating healthy food is…" The scale ranged from 1 (extremely–bad/not enjoyable) through 4 (neither) to 7 (extremely-good/enjoyable). Higher scores indicate a more positive explicit attitude towards healthy food.

#### 2.2.3. Implicit attitude

Implicit Association Task (IAT) indirectly assesses attitudes towards an object by measuring the strengths of associations among concepts through the reaction speed to the presentation of stimuli associated with the concepts. Inquisit 3.0 which measures response latencies to keyboard presses with millisecond accuracy was used to generate the test and collect the data. The IAT was presented in seven blocks, five of which were practice trials, to acquaint subjects with the stimulus materials and categorization rules. The target category exemplars comprised images of unhealthy (e.g., pizza, burger, chips) and healthy (e.g., salad, fruit, vegetables) foods; trials and analysis were performed according to Sartor et al. (2011).

#### 2.2.4. Phone application

Participants were asked to download the Mind Eating mobile phone application (Fig. 1) from the Apple store for IOS platform users, or to receive it as a file by email for Android users, and were individually instructed in its use. All inputs were prompted by the participants themselves; no cues to initiate inputs were generated by the program.

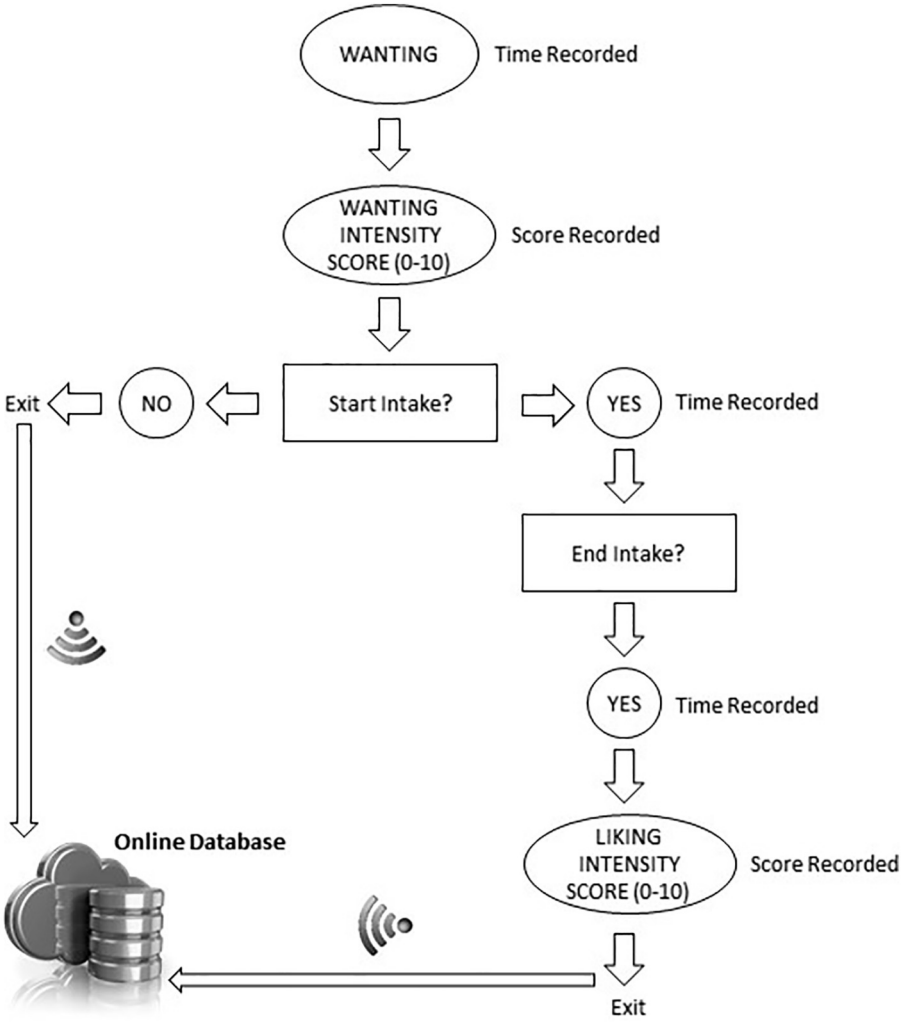


**Fig. 1.** Program structure of phone application for assessing wanting and liking associated with food intake.

Participants were asked to rate their food wanting, and to use the application to record and rate the strength of their perceived wanting for food on a scale between 0 (not at all) and 10 (very strongly) as it occurred, each time food wanting was perceived regardless of whether they were going to eat or not. They were then asked either to end the record or to record if they began eating. They were asked to enter liking events and their intensities defined as the perceived enjoyment of the food rated between 0 (didn't enjoy at all) and 10 (enjoyed it very much) immediately after each eating episode ended. We did so because we believe that the end of the meal is the natural time point for judging the consummatory reward from having just eaten. The participants recorded their perceptions over a period of 14 days. Data was collected via an on-line host.

Thus, the time point and intensity (score) of all food wanting episodes were captured for each participant and these could be divided into wanting that was resisted = resisted wanting and wanting leading to eating = un-resisted wanting. In addition all eating episodes and their durations were recorded along with the time points and intensity (score) of liking at the end of each eating episode.

### 2.3. Data analysis

Data were analyzed using IBM SPSS Statistics 22. Group-wise comparisons of body characteristics, data from the explicit attitude questionnaire and implicit attitude computer task were performed via analysis of variance (ANOVA) and *t*-test. Multiple analysis of covariance (MANCOVA) was performed using the nine craving dimensions from the food craving questionnaire (FCQ-T) as dependent variables, L- and H-groups as independent variable, and sex as the covariate followed by post hoc tests with Bonferroni correction. Between-group comparison of FCQ-T total was performed using analysis of covariance (ANCOVA) with sex as the covariate. Phone application parameters were compared between groups using MANCOVA, with age as the covariate followed by post hoc tests with Bonferroni correction. Derived phone application parameters were compared between groups via ANOVA. Pearson correlations were performed on selected parameters. All parameters are displayed in means and standard deviations in brackets.

## 3. Results

53 participants provided full sets of data from the smartphone application, and they completed all of the additional assessments. Baseline measures for the participants who dropped out of the study or who were excluded for technical reasons were not significantly different from the 53 participants who completed the study. Baselines measures for H-group (n = 20) and L-group (n = 33) are shown in Table 1. The two groups did not differ in age or of percentage of females, but, as expected, they differed in both BMI and body-fat percentage (see Table 1).

The H-group had significantly higher scores than the L-group on the following factors from the Food Craving Questionnaire (Cepeda-Benito et al., 2000): T2 (Anticipation of positive reinforcement that might result from eating), T4 (Lack of control over eating), T7 (Emotions that

**Table 1**
Descriptive characteristics for participants of L-group and H-group.

| Variable | L-group (n = 33) | H-group (n = 20) | Statistical comparison |
|---|---|---|---|
| Female (%) | 84.8 (n = 28) | 70.0 (n = 14) | $\chi 2(1) = 1.67$, p = 0.20 |
| Age (years) | 38.85 (11.36) | 40.25 (9.51) | t(51) = 0.46, p = 0.65 |
| BMI (kg/m$^2$) | 24.04 (3.32) | 34.84 (5.29) | t(51) = 9.16, p < 0.001* |
| Body fat (%) | 18.39 (6.57) | 42.34 (13.11) | t(24.88) = 7.61[a], p < 0.001* |

[a] Unequal variances *t*-test is reported due to significant Levene's test for equality of variances: F = 10.44, p = 0.002.
* Significant, p < 0.05.

might be experienced before or during food cravings or eating), T8 (Cues that might trigger food cravings), T9 (Guilt from having food cravings or giving in to them), and the FCQ total score (see Table 2). It is noteworthy that the two groups did not differ on T6 (craving as a physiological state e.g., hunger).

The H-group had a significantly less positive explicit attitude towards healthy food than the L-group, but the two groups did not differ in their implicit attitude towards healthy food, as measured by the IAT task, (see Table 3).

Using the phone application data, we report the following parameters to describe participants' eating behavior: Daily frequency of un-resisted wanting, resisted wanting, duration of eating events and un-resisted wanting fraction, which is the ratio of un-resisted wanting events to the total number of wanting events (the higher the score the smaller the proportion of food wanting events resisted). The rating scores for perceived food wanting, un-resisted wanting, resisted wanting, and food liking scores of the H- and L-groups are shown in Table 4. A MANCOVA in which participants' age was the covariate was used to compare H-group and L-group (parameters 1–5, Table 4). The H-group recorded significantly lower frequencies of un-resisted wanting of food, with resisted wanting frequency not being significantly different between groups. Un-resisted wanting fraction was not significantly different showing that about 30% of wanting events were resisted in both groups.

Within H-group, correlational analysis indicated that the un-resisted wanting fraction was significantly (p < 0.05) associated with craving: FCQ-T total (r = 0.553), T2 (r = 0.588), T5 (r = 0.529), and T8 (r = 0.623), but it was unrelated to the other craving dimensions. That is, in H-group the higher the level of craving, the less that food wanting was resisted. In the L-group, however, there were no significant correlations between the un-resisted wanting fraction and any of the food-craving dimensions. Additionally, in the H-group but not in the L-group un-resisted wanting fraction was significantly correlated (p < 0.05) with BMI (r = 0.613) and with body-fat percentage (r = 0.454), indicating that participants in the H-group who resisted less had a higher

**Table 3**
Implicit and explicit attitudes towards healthy food for participants in L-group and H-group.

| Attitude test/ questionnaire | L-group (n = 33) | H-group (n = 20) | F | P | Partial $\eta^2$ |
|---|---|---|---|---|---|
| Implicit score | 1.17 (0.21) | 1.14 (0.24) | 0.250 | 0.620 | 0.005 |
| Explicit score | 49.39 (5.25) | 45.05 (5.58) | 8.137 | 0.006* | 0.138 |

ANOVA – effect of group, see table.
* Significant, p < 0.05.

BMI and body-fat percentage. Finally, the mean duration of eating events in both groups were nearly equivalent (~18 min and ~17 min, respectively) and not significantly different from each other (see Table 4).

Records of intensity rating scores of wanting, un-resisted wanting and resisted wanting showed no significant differences between groups (Table 4). However, liking scores were significantly lower in the H-group compared with the L-group (Table 4). Additionally, when the two groups were combined, participants' liking scores were significantly negatively correlated (p < 0.01) with both their BMI (r = −0.360) and their body-fat percentage (r = −0.373). ANOVA analysis of within group differences between the levels of all intensity rating scores were significant in the L-group following the order resisted wanting < un-resisted wanting < liking, whereas there were no significant differences between the rating levels in the H-group (Fig. 2).

## 4. Discussion

In this study, we used a novel smartphone application to perform momentary ecological assessment of participants' eating behavior, with particular emphasis on their anticipation and consumption of food. In order to identify participants' motivation underlying their perception and consumption of food, we also assessed their level of craving and their implicit and explicit attitudes towards food.

The first question addressed was whether the smartphone data accurately reflected participants' naturalistic eating behavior. The smartphone application indicated significantly fewer un-resisted food wanting events in the H-group than in the L-group, but no difference in the number of resisted food wanting events between the two groups. The mean number of un-resisted food wanting events that participants in the L-group recorded per day (4.33 (1.26)) is comparable to the number recorded (4.8 (1.3)) in an earlier study under naturalistic conditions with a much larger sample size (n = 2385) (Aljuraiban et al., 2015). Furthermore, also consistent with our findings, the same study reported an inverse relationship between the frequency of participants' eating and their BMI, with other studies confirming this relationship (Mesas, Munoz-Pareja, Lopez-Garcia, & Rodriguez-Artalejo, 2012). In addition, our participants resisted approximately 30% of their food

**Table 2**
FCQ-T scores for participants in L-group and H-group.

| FCQ-T dimension | L-group (n = 33) | H-group (n = 20) | F | p | Partial $\eta^2$ |
|---|---|---|---|---|---|
| T1. Having intentions and plans to consume food | 10.85 (3.55) | 12.45 (3.00) | 3.646 | 0.062 | 0.068 |
| T2. Anticipation of positive reinforcement that may result from eating | 15.48 (4.68) | 18.30 (4.26) | 4.476 | 0.039* | 0.082 |
| T3. Anticipation of relief from negative states and feelings as a result of eating | 7.67 (3.01) | 9.40 (3.60) | 3.575 | 0.064 | 0.067 |
| T4. Lack of control over eating | 15.52 (4.85) | 18.50 (3.86) | 6.098 | 0.017* | 0.109 |
| T5. Thoughts or preoccupation with food | 19.06 (6.66) | 22.75 (10.06) | 3.942 | 0.053 | 0.073 |
| T6. Craving as a physiological state | 15.18 (2.73) | 16.00 (3.89) | 0.867 | 0.356 | 0.017 |
| T7. Emotions that may be experienced before or during food cravings or eating | 18.39 (6.62) | 25.00 (6.81) | 15.673 | < 0.001* | 0.239 |
| T8. Cues that may trigger food cravings | 13.30 (5.63) | 16.60 (5.96) | 6.356 | 0.015* | 0.113 |
| T9. Guilt from cravings and/or for giving into them | 9.94 (4.30) | 12.35 (3.36) | 6.400 | 0.015* | 0.113 |
| FCQ-T total | 125.39 (29.31) | 151.35 (33.87) | 11.230 | 0.002* | 0.183 |

MANCOVA (FCQT1-9), effect of group: Pillai's trace, V = 0.315, F(2,50) = 2.146, p = 0.046, partial $\eta^2$ = 0.315; covariate (sex): Pillai's trace, V = 0.186, F(1,50) = 1.068, p = 0.406, partial $\eta^2$ = 0.186; ANCOVA (FCQ-T Total) – effect of group, see table; covariate (sex) F(1,50) = 4.175, p = 0.046, partial $\eta^2$ = 0.077.
* Significant, p < 0.05.

**Table 4**
Phone application parameters for participants in L-group and H-group.

| Parameter | L-group (n = 33) | H-group (n = 20) | F | p | Partial $\eta^2$ |
|---|---|---|---|---|---|
| 1) Un-resisted wanting frequency ($day^{-1}$) = eating frequency | 4.33 (1.26) | 3.59 (0.85) | 5.807 | 0.020* | 0.104 |
| 2) Resisted wanting frequency ($day^{-1}$) | 2.00 (1.46) | 1.49 (0.91) | 1.766 | 0.190 | 0.034 |
| 3) Un-resisted wanting score | 7.00 (1.01) | 6.87 (1.07) | 0.194 | 0.662 | 0.004 |
| 4) Resisted wanting score | 6.02 (1.72) | 6.54 (1.29) | 1.331 | 0.254 | 0.026 |
| 5) Liking score | 7.65 (0.81) | 7.14 (1.04) | 4.713 | 0.035* | 0.086 |
| 6) Wanting frequency ($day^{-1}$) | 6.34 (2.00) | 5.07 (1.42) | 6.099 | 0.017* | 0.107 |
| 7) Wanting score | 6.72 (1.07) | 6.75 (1.04) | 0.009 | 0.926 | < 0.001 |
| 8) Un-resisted wanting fraction (un-resisted wanting frequency/all wanting frequency) | 0.71 (0.15) | 0.73 (0.13) | 0.117 | 0.734 | 0.002 |
| 9) Duration of eating/event (min:sec) | 17:42 (07:34) | 18:24 (08:22) | 1.093 | 0.301 | 0.021 |

MANCOVA (parameters 1–5), effect of group: Pillai's trace, V = 0.231, F(2,50) = 2.759, p = 0.029, partial $\eta^2$ = 0.231; covariate (age), Pillai's trace, V = 0.267, F(1,50) = 3.252, p = 0.012; partial $\eta^2$ = 0.267; ANOVA (parameters 6–9) – effect of group, see table.
* Significant, $p < 0.05$.

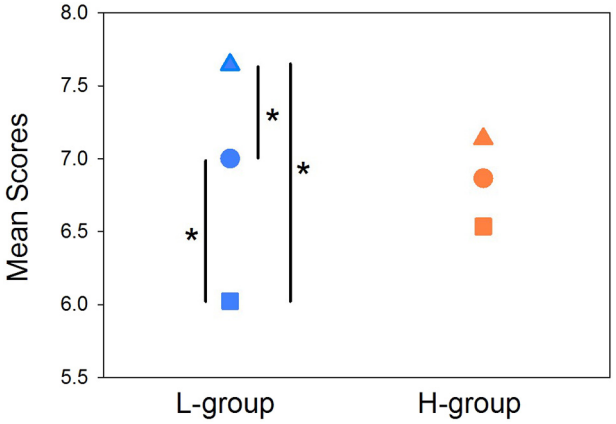


**Fig. 2.** Mean score levels of resisted wanting (squares), un-resisted wanting (circles), and liking (triangles) of L-group (blue symbols) and H-group (red symbols). * depicts significant ($p < 0.05$) differences between score means. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

wanting events, which is in agreement with Massey and Hill's results obtained under naturalistic conditions (Massey & Hill, 2012). They found that about 70% of the food cravings that both dieters and non-dieters reported resulted in eating. Finally, in our study participants in both groups had a mean meal duration of ~17 min, which is in accordance with earlier reports that meals lasted between 16 and 22 min, depending on the bite size taken (Spiegel, Kaplan, Tomassini, & Stellar, 1993).

In summary, the parameters of eating events that we identified in the current study are consistent with earlier studies. We concluded, therefore, that our results were suitable for a more in-depth analysis of associations among participants' psychological and physiological characteristics. We evaluated these associations in the context of the major theories of the causes of overeating. They suggest that overeating is mechanistically connected to alterations in overeaters' dopamine system in reward pathways in the brain (Johnson & Kenny, 2010; Wang et al., 2001). The major psychological mechanisms that have been proposed to be important in overeating are enhanced reward sensitization (Davis, Strachan, & Berkson, 2004) and anticipation (Nummenmaa et al., 2012), consummatory reward deficiency (Stice et al., 2008), and impaired ability to predict and learn the value of food rewards (Berridge, 2012; Zhang, Manson, Schiller, & Levy, 2014).

Contrary to the findings from brain imaging studies that used artificial food cues (Nummenmaa et al., 2012), in our naturalistic study we found no differences between the H-group and the L-group in the intensity of participants' un-resisted food wanting and resisted food wanting. However, consistent with our hypothesis we found that participants with a higher body fat percentage (H-group) experienced less consummatory reward from eating (less food liking) than participants in the L-group. Additionally, when the two groups of participants were combined, negative correlations were found between participants' food liking and their body-fat percentage and their BMI. When we consider these results together—the lack of a difference between H-group and L-group in food wanting but the significant negative association between participants' body characteristics and their food liking—this suggests support for the reward-deficiency theory of obesity rather than an elevated reward response or an enhanced anticipatory reward expectations among the participants in the H-group.

A negative association between reward sensitivity and BMI among participants with obesity was previously reported (Davis & Fox, 2008); individuals with obesity were also found to have reduced dopamine receptor density in brain areas crucial for consummatory reward (Wang et al., 2001). At the same time, a higher score in craving trait (FCQ-T total) in the H-group, and the positive association between craving and both body-fat percentage and BMI suggest that food wanting in the H-group and L-group might be influenced by different kinds of motives. It would seem that participants of the H-group were more influenced by hedonic drives related to their emotional state and responses to food cues instead of by reward expectations that had been learned from earlier experiences with particular foods. In fact, a stronger hedonic drive that influences food choices has frequently been reported among people with obesity (Mela, 2006). Additionally, in their *f*MRI study, Nummenmaa et al. (2012) found that although participants with or without obesity rated the pleasantness of anticipated food similarly, different patterns of activation were observed in the two groups in reward areas of their brain. Moreover, in animal models, dopamine-related manipulations have been found to alter food wanting, independent of past experiences with reward (see Berridge (2012)). Finally, our interpretation of the current results is further supported by the association that we found between the un-resisted food wanting fraction and craving (FCQ-T total), whereby participants in the H-group with higher craving were able to resist a smaller proportion of the food wanting events that they reported.

In the L-group, food liking was significantly higher than un-resisted food wanting, which, in turn, was significantly higher than resisted food wanting. This outcome is consistent with the expectation that in this group less intense food wanting events could be resisted and the more intense food wanting would lead to food consumption and, in turn, consummatory reward, which should be equal to or greater than the anticipated level. Certainly, based on the principles of positive and negative reinforcement, we would expect that previous experiences with food choices should result in this order (Epstein et al., 2007), although it was not seen in the ratings of participants in the H-group. It would appear that in deciding whether to eat, the participants in the H-group were less influenced by the intensity of their food wanting than were the participants in the L-group. This, together with H-group's significantly reduced food liking, suggests that either their ability to make reward-optimized food choices was impaired or that their

consummatory reward (food liking) was reduced in comparison to participants in the L-group. This possibility could be an important causative factor in obesity; in fact, Davis and Fox (2008) proposed that reward deficiency could result in a greater quantity of food being eaten in an attempt to compensate for the lack of enjoyment.

Considering that participants in this study made their individual choices about which foods to consume based on their individual characteristics and motivations and the specific environment that they were in and were not constrained in their choices by study parameters such as particular foods that could be eaten, their resisted and un-resisted food wanting would have been directed towards a variety of food targets. Although participants did not record the specific kinds food that they anticipated at each food-wanting event, participants were not dieting and H-group participants had more negative explicit attitudes towards healthy foods. Some researchers have found that participants' liking and wanting of sweet and high-fat foods differs from their perceptions of other kinds of foods (Dalton, Blundell, & Finlayson, 2013; Finlayson, King, & Blundell, 2008; French, Mitchell, Finlayson, Blundell, & Jeffery, 2014).

The main strength of this study is that participants recorded their food wanting and food liking in their natural environment whenever they were perceived. They recorded both the food-wanting events that they resisted and the food wanting that led to food consumption. This study, therefore, provides new insights into how food rewards are differentially perceived in adults with a higher and a lower body-fat percentage.

At the same time, the study has some limitations that should be acknowledged. First, allowing participants to use a smartphone application to record their food wanting and food liking events relied on their conscientiousness to input the data correctly. Undoubtedly, this method is susceptible to some underreporting, and only food wanting events and eating that participants were consciously aware of could be reported. Additionally, food wanting and food liking recorded in this manner were deliberately scored in a general rather than a relative manner; therefore, the scores are subjective and could not be confirmed by way of external calibration. Rogers and Hardman (2015) have, however, recently demonstrated the utility and validity of using participants' ratings of desire to eat as a measure of their food reward. The measures of food wanting and food liking that we used were, of course, different from other measures of wanting and liking, which have varied depending on the paradigm used and the time points of the measurement (Havermans, 2011). We aimed to maximize ecological validity by measuring food wanting and liking under naturalistic conditions.

## 5. Conclusions

The results of the present study showed that adults with a higher percentage of body-fat reported less enjoyment (less food liking) from food intake than adults with a lower percentage of body-fat. There was, however, no differentiation between intensity ratings of perceived resisted and non-resisted anticipatory (wanting) and consummatory food reward (liking) in people with higher percentage of body-fat. These results suggest that people with obesity are characterized by a reward deficiency. They also suggest that obesity is a complex problem in which food craving plays an increased role in food wanting. To better help people with obesity make permanent changes in their eating behavior in order to manage their weight, more attention needs to be paid to the reward value of eating for each individual.

## Acknowledgments

We thank Dr. David Markland for providing the implicit association task and attitude questionnaire.

This research was funded by a grant from Betsi Cadwaladr University Health Board (IRAS: 133102).

## References

Aljuraiban, G. S., Chan, Q., Griep, L. M. O., Brown, I. J., Daviglus, M. L., Stamler, J., et al. (2015). The impact of eating frequency and time of intake on nutrient quality and body mass index: The INTERMAP study, a population-based study. *Journal of the Academy of Nutrition and Dietetics, 115*(4), 528-U284. http://dx.doi.org/10.1016/j.jand.2014.11.017 (PubMed PMID: WOS:000351779000007).

Alshubrami, M., Alrajhi, S., Cox, W., & Kubis, H.-P. (2017). Effectiveness of a weight-loss intervention using self-monitoring practice with eating behavioral commandments in obese females, Riyadh, Saudi Arabia. *Saudi Journal of Obesity, 5*(2), 77–84. http://dx.doi.org/10.4103/sjo.sjo_15_17.

Berridge, K. C. (2009). 'Liking' and 'wanting' food rewards: Brain substrates and roles in eating disorders. *Physiology & Behavior, 97*(5), 537–550. http://dx.doi.org/10.1016/j.physbeh.2009.02.044 (PubMed PMID: WOS:000267729700006).

Berridge, K. C. (2012). From prediction error to incentive salience: mesolimbic computation of reward motivation. *European Journal of Neuroscience, 35*(7), 1124–1143. http://dx.doi.org/10.1111/j.1460-9568.2012.07990.x (PubMed PMID: WOS:000302360500014).

Berridge, K. C., & Robinson, T. E. (2003). Parsing reward (vol 26, pg 507, 2003). *Trends in Neurosciences, 26*(11), 581. http://dx.doi.org/10.1016/j.tins.2003.09.001 (PubMed PMID: WOS:000186452800004).

Cepeda-Benito, A., Gleaves, D. H., Williams, T. L., & Erath, S. A. (2000). The development and validation of the state and trait food-cravings questionnaires. *Behavior Therapy, 31*(1), 151–173. http://dx.doi.org/10.1016/s0005-7894(00)80009-x (PubMed PMID: WOS:000089674000008).

Courneya, K. S., & Bobick, T. M. (2000). Integrating the theory of planned behavior with the processes and stages of change in the exercise domain. *Psychology of Sport and Exercise, 1*(1), 41–56. https://doi.org/10.1016/S1469-0292(00)00006-6.

Dalton, M., Blundell, J., & Finlayson, G. (2013). Effect of BMI and binge eating on food reward and energy intake: Further evidence for a binge eating subtype of obesity. *Obesity Facts, 6*(4), 348–359. http://dx.doi.org/10.1159/000354599 (PubMed PMID: WOS:000324538700005).

Davis, C., & Fox, J. (2008). Sensitivity to reward and body mass index (BMI): Evidence for a non-linear relationship. *Appetite, 50*(1), 43–49. http://dx.doi.org/10.1016/j.appet.2007.05.007 (PubMed PMID: WOS:000251512500006).

Davis, C., Strachan, S., & Berkson, M. (2004). Sensitivity to reward: implications for overeating and overweight. *Appetite, 42*(2), 131–138. http://dx.doi.org/10.1016/j.appet.2003.07.004 (PubMed PMID: WOS:000220322600002).

Engel, S. G., Crosby, R. D., Thomas, G., Bond, D., Lavender, J. M., Mason, T., et al. (2016). Ecological momentary assessment in eating disorder and obesity research: A review of the recent literature. *Current Psychiatry Reports, 18*(4), http://dx.doi.org/10.1007/s11920-016-0672-7 (PubMed PMID: WOS:000371176800005).

Epstein, L. H., Temple, J. L., Neaderhiser, B. J., Salis, R. J., Erbe, R. W., & Leddy, J. J. (2007). Food reinforcement, the dopamine $D_2$ receptor genotype, and energy intake in obese and nonobese humans. *Behavioral Neuroscience, 121*(5), 877.

Finlayson, G., King, N., & Blundell, J. (2008). The role of implicit wanting in relation to explicit liking and wanting for food: Implications for appetite control. *Appetite, 50*(1), 120–127. http://dx.doi.org/10.1016/j.appet.2007.06.007 (PubMed PMID: WOS:000251512500014).

French, S. A., Mitchell, N. R., Finlayson, G., Blundell, J. E., & Jeffery, R. W. (2014). Questionnaire and laboratory measures of eating behavior. Associations with energy intake and BMI in a community sample of working adults. *Appetite, 72*, 50–58. http://dx.doi.org/10.1016/j.appet.2013.09.020 (PubMed PMID: WOS:000329268300007).

Goldschmidt, A. B., Crosby, R. D., Cao, L., Pearson, C. M., Utzinger, L. M., Pacanowski, C. R., et al. (2017). Contextual factors associated with eating in the absence of hunger among adults with obesity. *Eating Behaviors, 26*, 33–39. http://dx.doi.org/10.1016/j.eatbeh.2017.01.005 (PubMed PMID: WOS:000407741200006).

Havermans, R. C. (2011). "You say it's liking, i say it's wanting …". On the difficulty of disentangling food reward in man. *Appetite, 57*(1), 286–294. http://dx.doi.org/10.1016/j.appet.2011.05.310 (PubMed PMID: WOS:000293677900042).

Johnson, P. M., & Kenny, P. J. (2010). Dopamine D2 receptors in addiction-like reward dysfunction and compulsive eating in obese rats. *Nature Neuroscience, 13*(5), 635–641. http://dx.doi.org/10.1038/nn.2519 (PubMed PMID: WOS:000277065700023).

Kyle, U. G., Piccoli, A., & Pichard, C. (2003). Body composition measurements: interpretation finally made easy for clinical use. *Current Opinion in Clinical Nutrition and Metabolic Care, 6*(4), 387–393. http://dx.doi.org/10.1097/01.mco.0000078988.18774.3d (PubMed PMID: WOS:000184463000006).

Massey, A., & Hill, A. J. (2012). Dieting and food craving. A descriptive, quasi-prospective study. *Appetite, 58*(3), 781–785. http://dx.doi.org/10.1016/j.appet.2012.01.020 (PubMed PMID: WOS:000304336800002).

Mela, D. J. (2006). Eating for pleasure or just wanting to eat? Reconsidering sensory hedonic responses as a driver of obesity. *Appetite, 47*(1), 10–17. http://dx.doi.org/10.1016/j.appet.2006.02.006 (PubMed PMID: WOS:000239747400003).

Mesas, A. E., Munoz-Pareja, M., Lopez-Garcia, E., & Rodriguez-Artalejo, F. (2012). Selected eating behaviours and excess body weight: a systematic review. *Obesity Reviews, 13*(2), 106–135. http://dx.doi.org/10.1111/j.1467-789X.2011.00936.x (PubMed PMID: WOS:000298839800002).

Münzberg, H., Qualls-Creekmore, E., Yu, S., Morrison, C. D., & Berthoud, H.-R. (2016). Hedonics act in unison with the homeostatic system to unconsciously control body weight. *Frontiers in Nutrition, 3*.

Nummenmaa, L., Hirvonen, J., Hannukainen, J. C., Immonen, H., Lindroos, M. M., Salminen, P., et al. (2012). Dorsal striatum and its limbic connectivity mediate abnormal anticipatory reward processing in obesity. *PLoS One, 7*(2), http://dx.doi.org/10.1371/journal.pone.0031089 (PubMed PMID: WOS:000302178400027).

Pelchat, M. L. (2002). Of human bondage: Food craving, obsession, compulsion, and addiction. *Physiology & Behavior, 76*(3), 347–352. http://dx.doi.org/10.1016/s0031-9384(02)00757-6 (PubMed PMID: WOS:000177451000003).

Roefs, A., & Jansen, A. (2002). Implicit and explicit attitudes toward high-fat foods in obesity. *Journal of Abnormal Psychology, 111*(3), 517–521. http://dx.doi.org/10.1037//0021-843x.111.3.517 (PubMed PMID: WOS:000176960100012).

Rogers, P. J., & Hardman, C. A. (2015). Food reward. What it is and how to measure it. *Appetite, 90*, 1–15. http://dx.doi.org/10.1016/j.appet.2015.02.032 (PubMed PMID: WOS:000354584100001).

Sartor, F., Donaldson, L. F., Markland, D. A., Loveday, H., Jackson, M. J., & Kubis, H. P. (2011). Taste perception and implicit attitude toward sweet index and soft drink supplementation. *Appetite, 57*(1), 237–246. http://dx.doi.org/10.1016/j.appet.2011.05.107 (PubMed PMID: WOS:000293677900036.

Seger, J. C., Horn, D. B., Westman, E. C., Lindquist, R., Scinta, W., Richardson, L. A., et al. Obesity algorithm (R), presented by the American Society of Bariatric Physicians (R). www.obesityalgorithm.org, Accessed date: 31 December 2013.

Shah, N. R., & Braverman, E. R. (2012). Measuring adiposity in patients: The utility of body mass index (BMI), percent body fat, and leptin. *PLoS One, 7*(4), http://dx.doi.org/10.1371/journal.pone.0033308 (PubMed PMID: WOS:000304780500016).

Spiegel, T. A., Kaplan, J. M., Tomassini, A., & Stellar, E. (1993). Bite size, ingestion rate, and meal size in lean and obese women. *Appetite, 21*(2), 131–145. http://dx.doi.org/10.1016/0195-6663(93)90005-5 (PubMed PMID: WOS:A1993MF03900005).

Stice, E., Spoor, S., Bohon, C., Veldhuizen, M. G., & Small, D. M. (2008). Relation of reward from food intake and anticipated food intake to obesity: A functional magnetic resonance imaging study. *Journal of Abnormal Psychology, 117*(4), 924–935. http://dx.doi.org/10.1037/a0013600 (PubMed PMID: WOS:000260974500017).

Stice, E., Spoor, S., Ng, J., & Zald, D. H. (2009). Relation of obesity to consummatory and anticipatory food reward. *Physiology & Behavior, 97*(5), 551–560. http://dx.doi.org/10.1016/j.physbeh.2009.03.020 (PubMed PMID: WOS:000267729700007).

Stice, E., & Yokum, S. (2016). Gain in body fat is associated with increased striatal response to palatable food cues, whereas body fat stability is associated with decreased striatal response. *Journal of Neuroscience, 36*(26), 6949–6956. http://dx.doi.org/10.1523/jneurosci.4365-15.2016 (PubMed PMID: WOS:000379020200011.

Volkow, N. D., Wang, G. J., Telang, F., Fowler, J. S., Thanos, P. K., Logan, J., et al. (2008). Low dopamine striatal D2 receptors are associated with prefrontal metabolism in obese subjects: Possible contributing factors. *NeuroImage, 42*(4), 1537–1543. http://dx.doi.org/10.1016/j.neuroimage.2008.06.002 (PubMed PMID: WOS:000259401000026).

Wang, G. J., Volkow, N. D., Logan, J., Pappas, N. R., Wong, C. T., Zhu, W., et al. (2001). Brain dopamine and obesity. *Lancet, 357*(9253), 354–357. http://dx.doi.org/10.1016/s0140-6736(00)03643-6 (PubMed PMID: WOS:000166897900014).

Yu, Y. H., Vasselli, J. R., Zhang, Y., Mechanick, J. I., Korner, J., & Peterli, R. (2015). Metabolic vs. hedonic obesity: a conceptual distinction and its clinical implications. *Obesity Reviews, 16*(3), 234–247. http://dx.doi.org/10.1111/obr.12246 (PubMed PMID: WOS:000350286800004).

Zhang, Z. H., Manson, K. F., Schiller, D., & Levy, I. (2014). Impaired associative learning with food rewards in obese women. *Current Biology, 24*(15), 1731–1736. http://dx.doi.org/10.1016/j.cub.2014.05.075 (PubMed PMID: WOS:000340074100020).